Environmental Impact and Safe Vegetable Production of Korean Organic Farming only Appling Organic Fertilizer to Maintain/Increase Soil Fertility

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ABSTRACT

In order to get some basic data to check the environmental sound function against soil and water pollution and the safe vegetable production by korean organic farming where an internationally recognized basic concepts of soil fertility management for organic farming is not practiced and only applying the organic fertilizer to maintain the soil fertility, the chemical characteristics of soils and NO_3^- content of chinese cabbage and lettuce cultivated by the conventional farming, greenhouse cultivation and organic farming were investigated.

The highest value of NO_3^--N in 0~30cm subsoil among the three different farming systems was found in the subsoil of organic farming, and it was 3.6 and 6.6 times higher than those of conventional farming in chinese cabbage and lettuce respectively. P_2O_5 accumulation in the rhizosphere by organic farming also showed the highest value. The accumulation of NO_3^--N and P_2O_5 in organic farming soil were similar or even more higher to those of greenhouse cultivation. The NO_3^- accumulation in the vegetable by organic farming reached 3224ppm for chinese cabbage and 2543ppm for lettuce, and it were 4.7 and 6.4 times higher than those by conventional farming.

It was concluded that there is urgently necessary to introduce the main concepts of soil fertility management of the Basic Standard of IFOAM, EU regulation and

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FAO/WHO Codex Alimentarius on organic agriculture(draft) into korean organic agriculture for the operation of environmental sound system and the production of safe vegetable in terms of NO_3^- content.

Ⅰ. INTRODUCTION

The production and consumption for organic vegetable is growing rapidly along with the income increase of the population and the consumer's demand for health food in Korea.

Recently the number of organic farmer is continually increased after Great Seoul City Council(GSCC) and National Agricultural Cooperation Federation(NACF) introduced a financial support system to an organic farmer in Paldang watershed area where supplies the drinking water for the population in Great Seoul. Second, GSCC and NACF together open numerous special markets for organic products in Great Seoul. It stimulates successfully consumers' interest to purchase an organic product. Third, government promotes the organic agriculture by the government certification system to guarantee it's quality. Furthermore it has been considering to introduce the direct payment system for organic farmer and the financial support for composting facility.

Consequently not only organic farmer but also the public suppose that organic vegetable is safe, and organic farming is environmentally sound. But surprisingly several reports(Sohn, 1994_1, 1994_2, 1995_2, 1995_3) had pointed out that korean organic farming is practiced in quite different way from Basic Standards of International Federation of Organic Agriculture Movement(IFOAM, 1994), EEC Regulation for Organic Agriculture(IFOAM, 1993), and Codex guidelines for organic agriculture (FAO/WHO, 1998). And as National Agricultural Product Inspection Agency(1996), Sohn(1994_1) and Sohn et al(1996) unveiled that the higher nitrate content in organically cultivated vegetables compare to those in conventionally cultivated one, it gives basically the huge controversy to korean organic agriculture.

The Far-East Asian organic farming including Korea which was developed by several pioneers in believing of application of compost and cattle manure as the only one tool for soil management to maintain or increase the soil and biological fertility to the extent of that adequate nutrition of the crop. The organic farming methods for crop production is being practiced quite differently from internationally recognized basic standards for organic agriculture(see, Tab.1). Therefore the organic farming should be checked whether it ensures an environmental sound function in terms of soil and water pollution and it produces a safe vegetable in terms of high NO_3^- content or not. And the korean organic farming has never gotten such opportunity at all to be proved its environmental impact by scientific determination(Sohn, 1995₃ ; Sohn et al, 1996) before.

Table 1. The Differences in basic methods and concepts between internationally recognized basic standards for organic agriculture and Korean organic farming to maintain or increase the soil and biological fertility.

Methods	Requirement / Practice	
	Internationally recognized basic standards for organic agriculture*	Korean organic agriculture
Rotation	Yes	No
Legume crops	Yes	No
Green manure	Yes	No
Deep rooting plants	Yes	No
Manure and compost	Yes	Yes
	Substances may be applied only to the extent that adequate nutrition of the crop are not possible by the above methods	only depend upon the application of organic fertilizer in the range of 20-100t/ha/year to cultivate the crop

* Internationally recognized standard, regulation or guidelines such as IFOAM Basic Standards, EU Regulations and FAO/WHO Codex alimentarius for organically grown foods belong to this category.

In this paper the chemical characteristics of soils and NO_3^- content of chinese cabbage and lettuce cultivated by the conventional farming(CF), greenhouse cultivation(GhC) and organic farming(OF) were investigated in order to get some basic data on an environmental sound function against soil and water pollution and the safe vegetable production in terms of NO_3^- content by the korean organic farming.

II. MATERIALS and METHOD

1. Sampling site, soil and plant sampling

In order to check the chemical characteristics in rhizosphere and NO_3^- accumulation in edible parts of vegetable between the three different farming methods, plant and soil samples were collected from 60 conventional farming site, 36 greenhouse cultivation site and 30 organic farming site for chinese cabbage and lettuce between June 1996 and September 1996 in Yongin/Kyunggi province, Cheonan and Asan/Chungnam province.

Soil and plant samples were took with 3 replications per farm site, and for soil samples in different soil depth of 0~30cm and 30~60cm per each replication, respectively. Both soil and plant samples were transported to laboratory quickly with controlled condition of under 4℃.

2. Determination of chemical characteristics for soil and plant

The content of NO_3^- was analysed by *E.coli* cell method modified by Sohn et al(1997 ; RDA, 1997). To prepare the sample extract, a 10g of fresh plant material is extracted for 1 hours in 100ml twice distilled water or a 100g of fresh soil is extracted for 30 minutes in 250ml of 0.025N $CaCl_2$ solution and then filtered with No. 2 filter paper. An aliquots of the extracts (usually 0.1ml), containing 1~30μg NO_3^--N, is pipetted into a test tube, the test suspension(usually 1ml with NaR activity at least 30μg NO_3^--N/10 min) added and the incubation preparation is gassed for one minute with N_2, using an injection needle. The test tube is closed so that it is gas-proof and incubated for 30 minutes in a waterbath at 37℃. 2ml of nitrite test reagent(sulfamil amide and N-(1-naphtyl)-ethlene diamine dihydrochloride) are then added, left to stand for 15 minutes to allow the color to develop, transferred quantitatively to a 100ml measuring flask and brought up to volume. Measurement against a blank is at 540nm using UV-spectrophotometer(Milton Roy Model : Spectronic 601).

The value of pH and E.C., and the content of Total-N and P_2O_5 were analysed by soil analytical manual of RDA/Korea.

Ⅲ. RESULTS and DISCUSSION

1. Difference of chemical characteristics in different soil depth of rhizosphere by different farming methods

The chemical characteristics of soils cultivated longer than 5 years by CF, GhC and OF were analysed(Tab.2). The average pH in CF soils is 6.4 for chinese cabbage and 6.7 for lettuce, while those of GhC and OF show 6.2, 6.5 and 5.9, 5.7 respectively. The value of pH slowly decreased in order of CF<GhC<OF as Chung et al(1994)

described GhC soils were more acidified than CF soils. Charles(1992) and Frederick et al(1993) suggested that nitric acid, sulfuric acid, phosphoric acid which were generated in the process of decomposition of soil organic matter due to decrease an acidity in the OF soil.

Table 2. Chemical characteristics of farmland soils practiced by conventional farming, greenhouse cultivation and organic farming

Farming method	Crop	Soil depth	pH (1:5 H_2O)	T-C (%)	P_2O_5 (ppm)	EC (mS/cm)
Conventional farming (CF)	Chinese cabbage	0~30cm	6.4	0.04	498	0.8
		30~60cm	6.2	0.03	159	0.5
	Lettuce	0~30cm	6.7	0.02	327	0.7
		30~60cm	6.2	0.02	206	0.3
Greenhouse cultivation (GhC)	Chinese cabbage	0~30cm	6.2	0.04	670	1.6
		30~60cm	5.8	0.02	220	1.1
	Lettuce	0~30cm	6.5	0.04	521	1.8
		30~60cm	6.5	0.03	315	0.6
Organic farming (OF)	Chinese cabbage	0~30cm	5.9	0.17	769	2.0
		30~60cm	5.8	0.10	717	1.6
	Lettuce	0~30cm	5.7	0.12	938	2.3
		30~60cm	5.3	0.07	462	1.5

The contents of total-N appear no difference between CF soils and GhC soils, but show relatively higher value in OF soils. There is no doubt that as the application rate of compost increases, the content of total-N in soil goes higher(Lee et al, 1996)

Figure 1 shows the frequency of P_2O_5 content in 0~30cm rhizosphere of chinese cabbage and lettuce cultivated by different farming methods. It gives clearly the severe phosphate accumulation was found in the soil practiced by OF, and as much as 56% of OF soils contain more than 800ppm P_2O_5 while 56% of CF soils contain less than 400ppm P_2O_5.

The average content of P_2O_5 in soils are high in order of OF>GhC>CF as table 1, but 769ppm, 670ppm, 498ppm for chinese cabbage and 938ppm, 521ppm, 327ppm for lettuce respectively. These value are 1.8 and 2,2 times higher in OF soils and 1.2 and 2.2 times higher in GhC soils for chinese cabbage and lettuce respectively compare to the appropriate content of P_2O_5 in soil suggested by Yoneyama(1993)

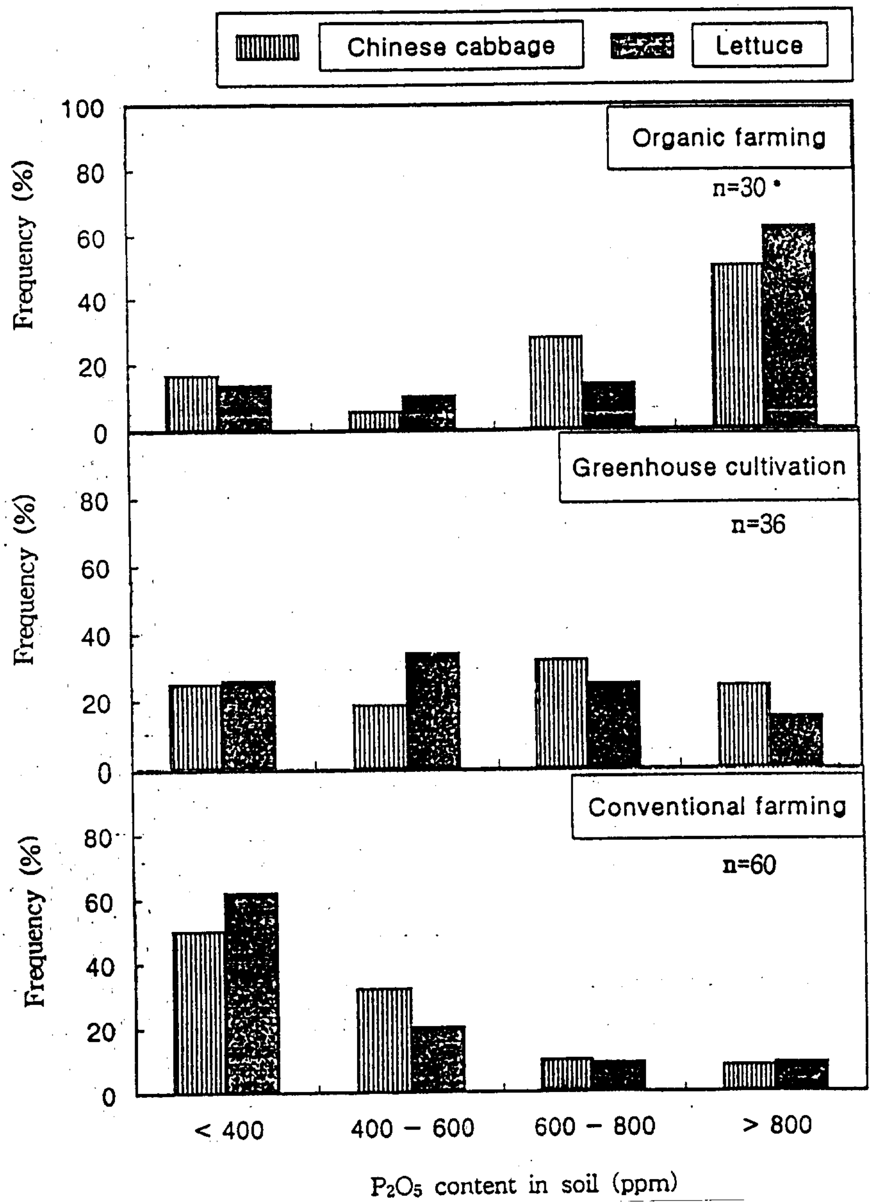

Fig 1. Frequency of P_2O_5 content in 0~30cm rhizosphere of chinese cabbage and lettuce cultivated by different farming methods.

The reason why average P_2O_5 contents are much higher in OF soils(769ppm-938ppm) than those in CF soils(327ppm-498ppm) is considered that organic farmer in Korea usually apply too much an organic fertilizer year after year such as cattle manure and compost contained a lot of phosphate, then it cause the P_2O_5 accumulation in OF soil. Similar result was found by Lee(1991) that the P_2O_5 accumulation in GhC and OF soil were 4-5 times high than those in CF soil. The P_2O_5 accumulation in rhizosphere is one of the very serious problems of korean OF which should be solved in the very near future. But the problem of phosphate accumulation could not been solved or gotten out as far as the organic farmer in Korea only apply cattle manure and compost to meet the need of nitrogen for crops(Park, 1996 ; Sohn et al, 1996). And it is still the unsolved mystery that organic farmer in the country believe the system operate although they only apply cattle manure and compost, but reality is so much different as above(Sohn and Chung, 1997).

In order to overcome the phosphate accumulation of soil and to achieve an environmental sound agriculture, the korean organic agriculture should introduce the Basic Standard of IFOAM(Sohn, 1995_3 ; Sohn et al, 1996) prescribed the rotation, cultivation of green manure and legume to maintain soil fertility and appropriate applying of compost.

Same tendency was found also in the electricity conductivity(EC) showing 2.0mS/cm and 2.3mS/cm in OF soils, 1.6mS/cm and 1.8mS/cm in GhC soils, and 0.8mS/cm and 0.7mS/cm in CF soils for chinese cabbage and lettuce respectively. It was similar with Kim(1996) reported the salt accumulation was much higher in OF soil than CF soil.

Table 3 shows the contents of NO_3^--N in top and subsoil practiced by the three different farming methods. The content range of NO_3^--N in CF topsoil(0~30cm) were 6-50ppm for chinese cabbage and 7-33ppm for lettuce, whereas 8-212ppm, 22-228ppm for GhC topsoil and 4-256ppm, 5-255ppm for OF topsoil. The NO_3^--N contents in OF soils were so much high as those in GhC soils, and sometimes even more.

The average contents of NO_3^--N in rhizosphere of farmland cultivated for chinese cabbage were 18ppm in CF soils, 64ppm for GhC and OF soils. The average contents of NO_3^--N in rhizosphere of GhC and OF soils for chinese cabbage cultivation were 3.6, 3.6 times higher than those in CF soils for chinese cabbage cultivation, and for lettuce cultivation it were even 5.3, 6.6 times high. The accumulation of NO_3^--N in OF soils was the severest one among the three different farming methods as Figure 2.

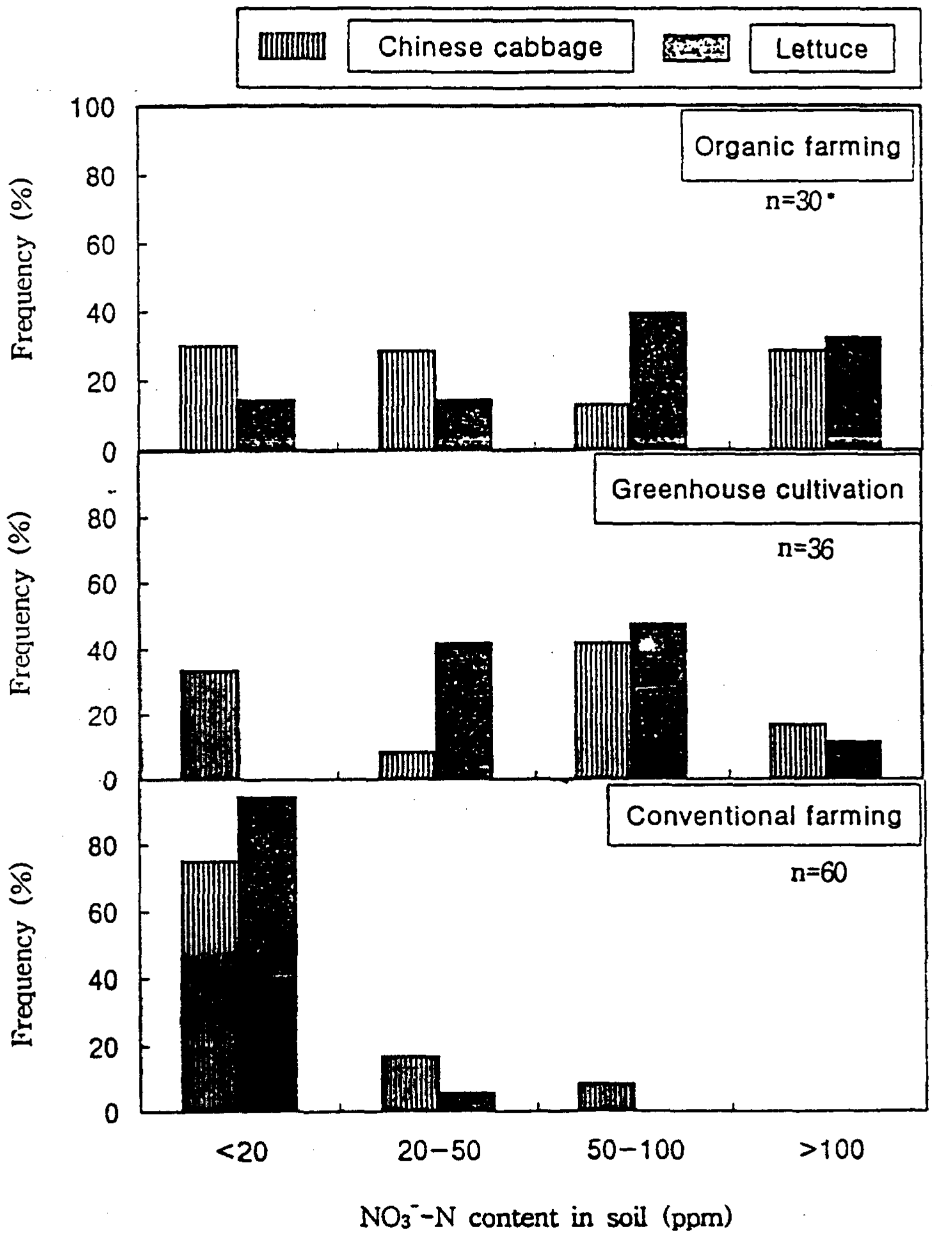

Fig 2. Frequency of NO_3^--N content in 0~30cm rhizosphere of chinese cabbage and lettuce cultivated by different farming methods.

Such result was similar with Shin(1988) reported the soil of greenhouse changes into saline soil which gets characteristics of salt accumulation year by year. And Sohn(1994)

$\cdot_2$, $1995_{1\cdot2}$) also found out the overuse of cattle manure and compost in OF caused the high accumulation of NO_3^--N in rhizosphere. It agreed with early report(Sohn et al, 1996) indicated the accumulation of NO_3^--N in rooted soil layer of OF system in Paldang watershed area was much higher than that of CF system. Surprisingly Goda et al(1985) also found the same problem of NO_3^--N accumulation in the GhC and OF soils in Japan.

Table 3. NO_3^--N content in 0~30㎝, 30~60㎝ soil depth of chinese cabbage and lettuce cultivated by conventional farming, greenhouse cultivation and organic farming.

Crop	Farming method	Soil depth	Range of NO_3^- content (ppm/F.W.)	Average content (NO_3^--N ppm)
Chinese cabbage	Conventional farming(CF)	0~30㎝	6~50	18
		30~60㎝	5~60	15
	Greenhouse cultivation(GhC)	0~30㎝	8~212	64
		30~60㎝	9~87	36
	Organic farming(OF)	0~30㎝	4~256	64
		30~60㎝	13~160	71
Lettuce	Conventional farming(CF)	0~30㎝	7~33	13
		30~60㎝	5~23	11
	Greenhouse cultivation(GhC)	0~30㎝	22~228	69
		30~60㎝	13~200	48
	Organic farming(OF)	0~30㎝	5~255	86
		30~60㎝	9~198	70

NO_3^--N content in OF subsoil(30~60㎝) was 71ppm while it was 15ppm in CF subsoil as figure 3. The NO_3^--N accumulations in OF subsoil were 4.7 times severer for chinese cabbage and 4.1 times severer for lettuce than those in CF subsoil. Furthermore it was simple 2 times higher for chinese cabbage and 1.5 times higher for lettuce compare to those of GhC subsoil where has the severe problem of salt accumulation and groundwater pollution by nitrate leaching.

Since such high concentration of NO_3^--N in the rhizosphere might lead to groundwater pollution by nitrate leaching, an intensive introduction of vegetable cultivation by OF in watershed area could be caused to the drinkwater pollution by nitrate more than that by CF.

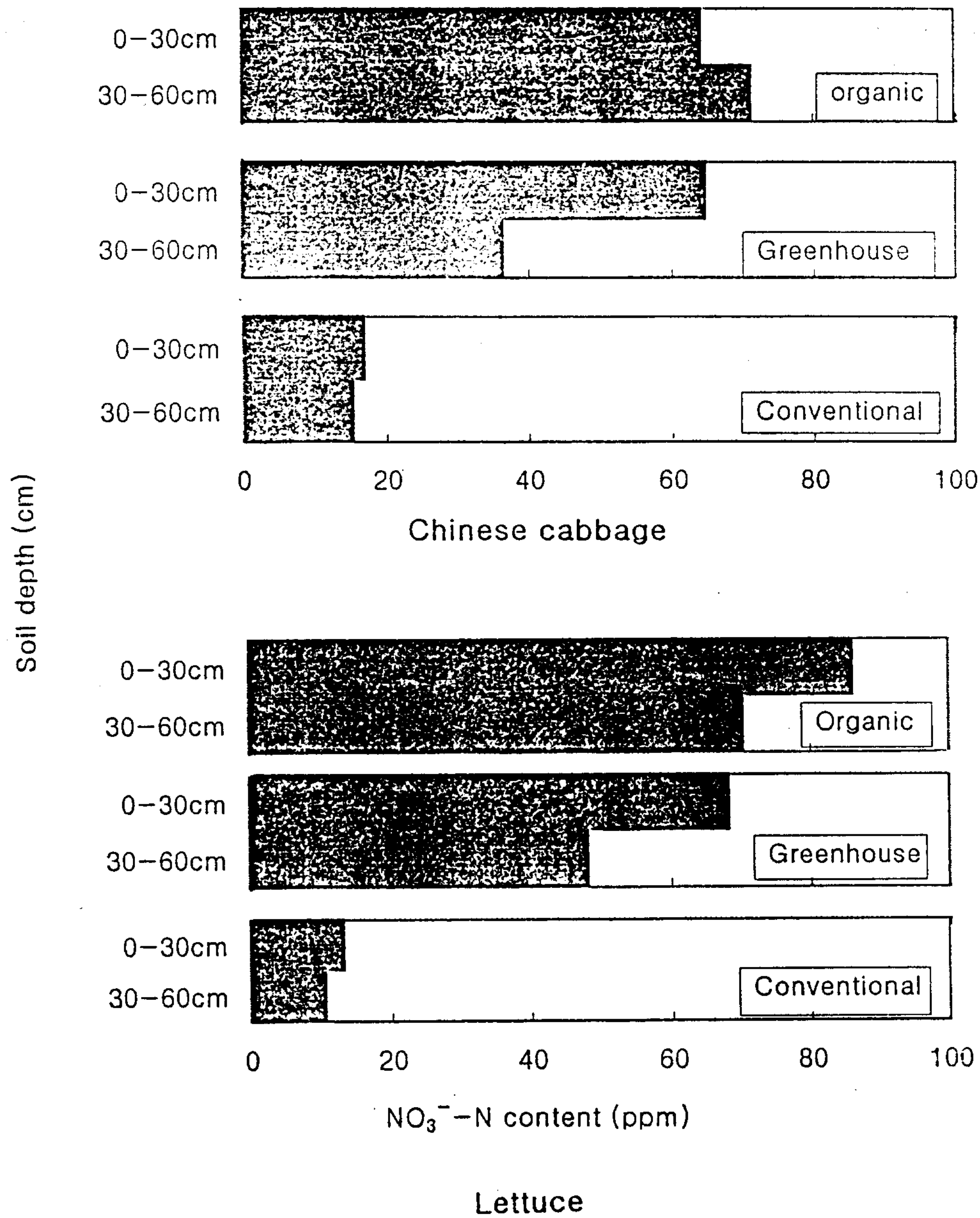

Fig 3. NO_3^--N content in 0~30, 30~60㎝ soil depth of chinese cabbage and lettuce cultivated by different farming methods.

The reason why such high NO_3^--N content was found not only in top soil but also OF subsoil compare to those of GhC and CF subsoil is that the organic farmer in the country apply too much cattle manure and compost in every 2-5 cultivations per year. Hong(1993) also suggested that even organic fertilizer if it is overused might cause the pollution of groundwater by nitrate leaching, and Yoon and Yoo(1993) pointed out that application of over 50t/ha of organic fertilizer leads a severe nitrate leaching.

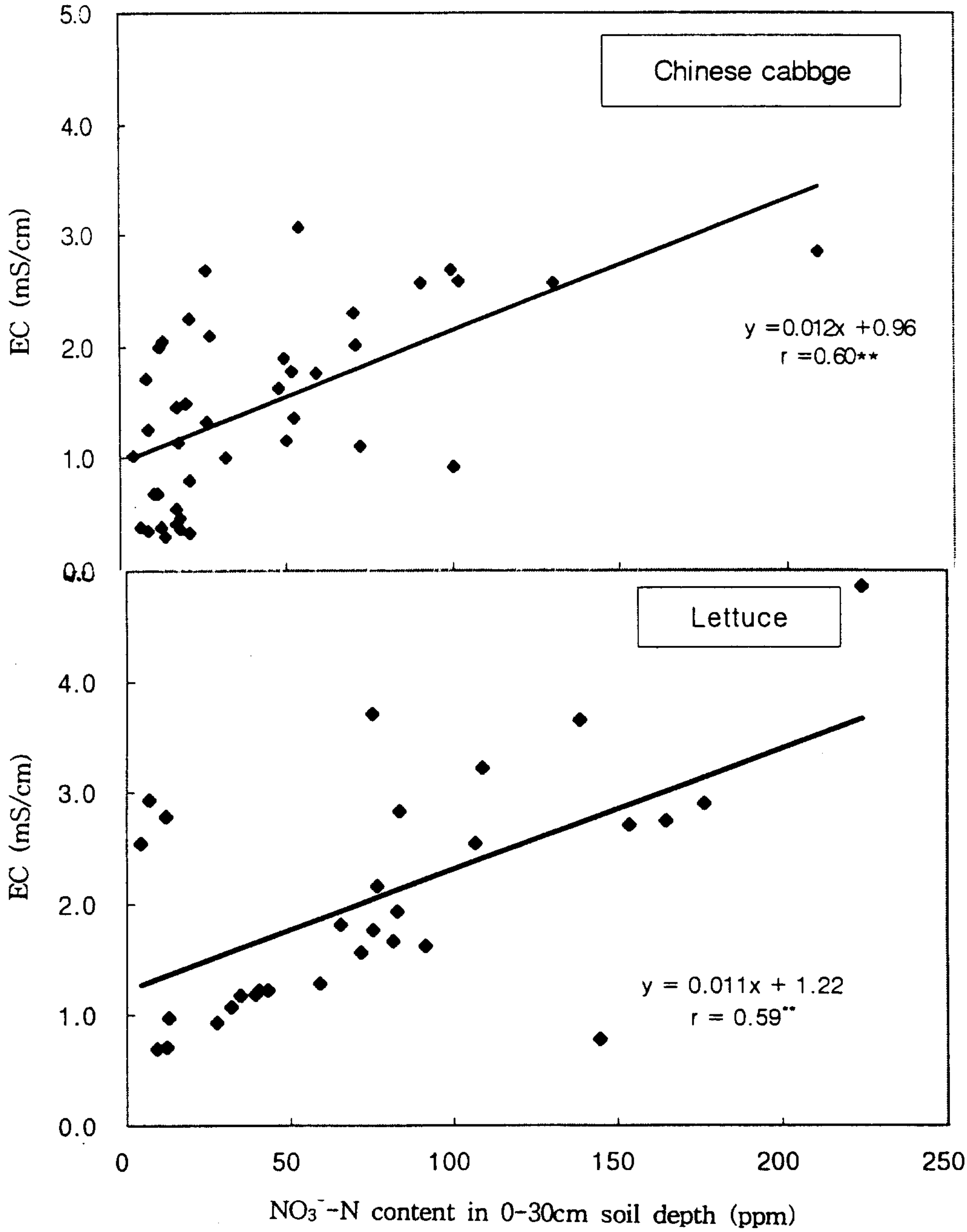

Fig 4. Correlation between NO_3^--N content and E.C. in 0~30㎝ soil depth of chinese cabbage and lettuce

Figure 4 shows the relationship between the content of NO_3^--N content and the value of E.C. in 0~30cm soil depth. The correlation coefficients(r) were found for 0.60** chinese cabbage and 0.59** for lettuce. It suggest the very close relation between the content of NO_3^--N and the concentration of salt in the rooted soil layer. This was coincident with Lee et al(1983) and Kim et al(1990) reported the close relation between the salt concentration and the anion concentration and NO_3^--N is an influence for salt concentration and with Goda et al(1985) reported the positive relation between the content of NO_3^--N and the value of E.C. in the soil profile.

As the result of chemical determination for soil characteristics it became clear that not only NO_3^--N and E.C. but also the concentration of phosphate in the farmland of OF was the highest among the three different farming methods. Hong(1996) also found the increase of nitrogen, phosphate, potassium concentration in case of organic fertilizer was overused. Korean organic farmer should have to apply huge amount of organic fertilizer such as cattle manure and compost to meet the nitrogen need of crop, since they do not know the rotation, green manure and legume cultivation to enhance the soil fertility including soil nitrogen availability at all. Therefore, only one strategy to apply cattle manure and compost to practice the OF has no other way to cause a high accumulation of phosphate and NO_3^--N(Sohn et al, 1996).

In order to minimize such potential risk of soil and water pollution by the high accumulation of nitrate and phosphate in OF soil, an organic farmer in the country should keep in mind that european organic farming which keeps the Basic Standard of IFOAM has a positive effect on mitigation of salt accumulation in rhizosphere(UBA, 1994 ; Green peace, 1992) and mitigation of water pollution by nitrate leaching(Green peace, 1992), and moreover they have to reconsider to change their wrong orientation on OF that the system operates even they only apply organic fertilizer such as cattle manure and compost. As the IFOAM Basic Standard(IFOAM, 1994), EEC Regulation and FAO/WHO Codex guidelines prescribe to organic farmer what they have to do for organic agriculture, cultivation of green manure, rotation and legume to enhance the soil fertility are the minimum requirements for organic agricultural production system. Thereafter, an appropriate application of cattle manure and compost is recommended in the IFOAM Basic Standard if crop require an additional input for optimum growth (IFOAM, 1994). Consequently it seems to be clear that actual problems such as accumulation of NO_3^--N and phosphate could be eliminated all at once if the korean organic agriculture introduces an internationally recognized core aspects of organic agriculture into an enactment of so-called Basic Standard of korean organic agriculture.

2. Difference of NO_3^- accumulation in vegetables by conventional farming, greenhouse cultivation and organic farming

The average and range of NO_3^- accumulation in chinese cabbage and lettuce cultivated by different farming systems are shown in table 4. NO_3^- in chinese cabbage were accumulated at 430~3410ppm(mean 1586ppm) by CF, 904~4631ppm(mean 3077ppm) by GhC and 2135~4742ppm(mean 3224ppm) by GhC, while NO_3^- in lettuce were accumulated at 472~2455ppm(mean 1537ppm) by CF, 1608~3452ppm(mean 2455ppm) by GhC and 679~4680 ppm(mean 2543ppm) by OF. It shows the the NO_3^- accumulation in chinese cabbage and lettuce by different farming systems is high in order of CF<GhC<OF, but the NO_3^- accumulation in chinese cabbage is higher than that in lettuce.

This result was opposite to Rauter and Wolkerstofer(1982) indicated the NO_3^- accumulation of vegetables cultivated by OF were rather lower than those by CF, it is due to overuse of cattle manure and compost in korean organic agriculture further beyond the nitrogen need of crop(Sohn and Oh, 1993 ; Sohn, 1994_2 ; Sohn, 1995_1 ; Sohn et al, 1996). The overuse of organic fertilizer causes the high concentration NO_3^--N in rhizosphere and it consequently produces the high nitrate accumulated vegetable.

Table 4. Accumulation NO_3^- in chinese cabbage and lettuce by conventional farming, greenhouse cultivation and organic farming

Crop	Farming method	Range of NO_3^- content (ppm/F.W.)	Average content (NO_3^- ppm/F.W.)
Chinese cabbage	Conventional farming(CF)	430~3410	1586
	Greenhouse cultivation(GhC)	904~4631	3077
	Organic farming(OF)	2135~4742	3224
Lettuce	Conventional farming(CF)	472~2455	1537
	Greenhouse cultivation(GhC)	1608~3452	2455
	Organic farming(OF)	679~4680	2543

As the distribution ranges of the NO_3^- accumulation by different farming systems shows in figure 5, the ratio of lettuce cultivated by CF which got over 2000ppm NO_3^- was lower at 11%, whereas those by GhC and OF were high at 81% and 79%. And in case of chinese cabbage it was low at 18% by CF, but high at 83% and 100% by GhC and OF, respectively. It was similar to the latest reports that vegetables grown in greenhouse(Sohn et al, 1995 ; Park et al, 1994) and by organic agriculture(Park et al, 1994 ; Sohn and Oh, 1993 ; Sohn, 1994l ; Sohn et al, 1996) got rather higher NO_3^- content compare to those by conventional agriculture.

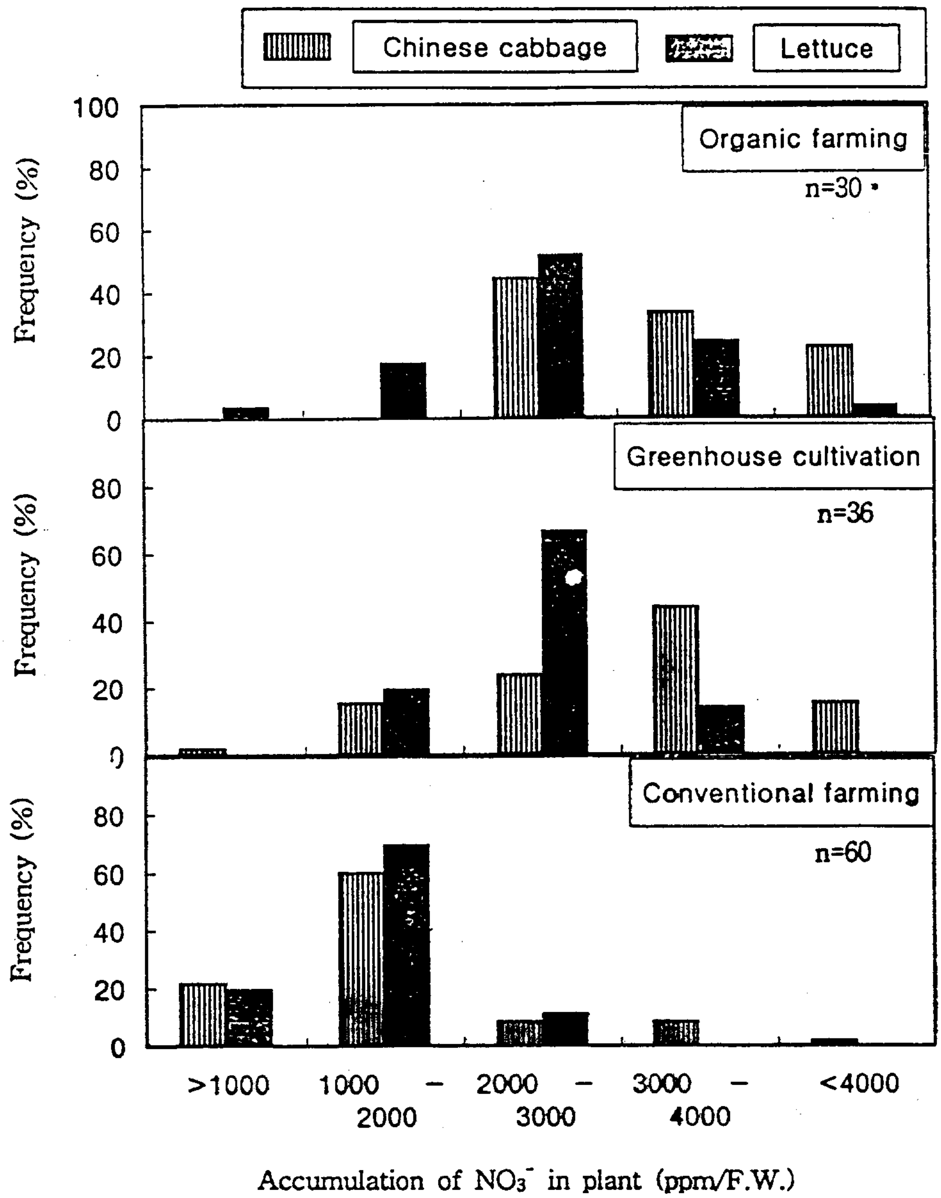

Fig 5. Frequency of accumulation NO_3^- in chinese cabbage and lettuce by different farming methods.

3. Relationship between NO_3^--N content in rhizosphere and NO_3^- accumulation of vegetables

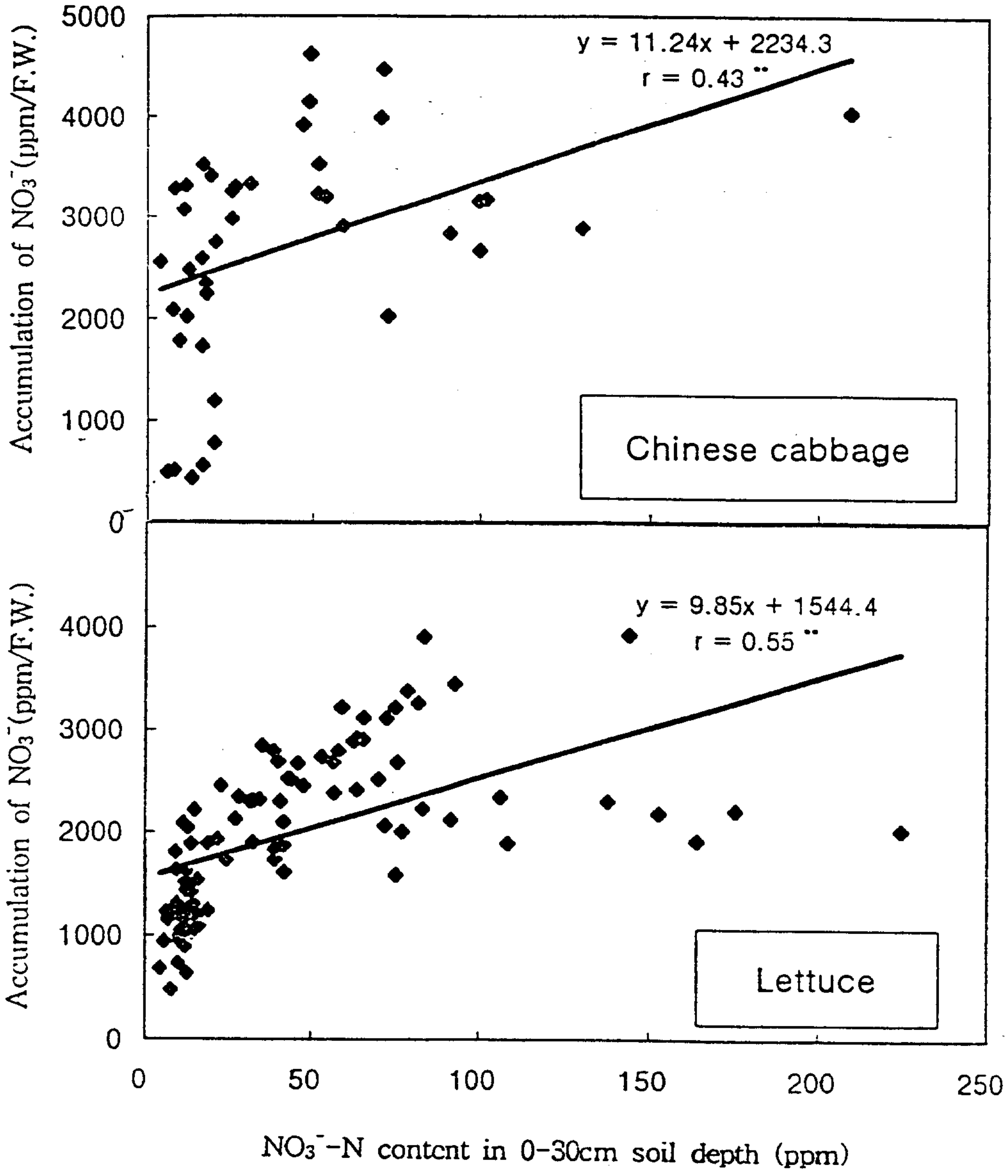

Fig 6. Correlation between NO_3^--N content in 0~30 soil depth and accumulation of NO_3^- in chinese cabbage and lettuce

Table 6 shows the relationship between NO_3^--N content in rhizosphere and NO_3^- accumulation of vegetables. The correlation coefficients(r) between NO_3^--N content in rhizosphere and NO_3^- accumulation of vegetable were found 0.43** for chinese cabbage and 0.55** for lettuce. Such high positive correlation indicates that the higher NO_3^--N content in rhizosphere is, the more accumulated NO_3^- in vegetables. This coincides with Claus(1983), Scharpf(1991) and Sohn ($1994_{1\cdot 2}$, $1995_{1\cdot 2}$) reported the high correlation between NO_3^--N content in rhizosphere and NO_3^- accumulation of vegetable.

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